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Evaluating ecological states of rocky intertidal communities: A Best Professional Judgment exercise

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ABSTRACT

A Best Professional Judgment (BPJ) exercise was performed to determine the level of agreement among experts in evaluating the ecological states of western North American rocky intertidal communities. Species-abundance and environmental data from 12 central and 11 southern California sites were provided to 14 experts who independently ranked communities from best to worst and assigned each to one of five categories based on the degree of deviation from an expected natural biological state. Experts achieved Spearman correlations of 0.49 (central California) and 0.30 (southern California) in their rankings and averaged 75.4% and 70.0% Euclidean Similarity (ES) in their community evaluations. These ES values compare favorably with agreement levels found for similar exercises with soft bottom macroinvertebrate assemblages. The experts emphasized macrophytes with functional characteristics related to morphology and sessile macroinvertebrates in their assessments. Several challenges were noted in interpreting rocky intertidal data sets, the most prominent of which are high spatial and temporal variation and site-to-site differences in natural disturbance regimes, features that lead to multiple, expected community states. Experts required detailed, physical habitat descriptions to develop community composition expectations that differed for different shore types, and expressed concern about evaluating rocky intertidal communities based on only a single sampling event. Distinguishing natural from anthropogenic disturbance without information on the sources and magnitudes of anthropogenic perturbation was also found to be challenging because the biological responses to these stressors are often similar. This study underscores the need for long-term data sets that describe the dynamics of populations and communities and rigorous testing of expert judgments to firmly establish broadly applicable and consistent links between community states and anthropogenic stressors on rocky shores.

1. Introduction

Coastal managers often rely on species composition and abundance data to evaluate the ecological states of biological communities and to interpret the extent of anthropogenic impacts. Although multivariate approaches, such as non-metric multidimensional scaling (Clarke and Gorley, 2006), are powerful tools for differentiating community structures, analyses based on biological data can be difficult to interpret, particularly when the effects of multiple potential stressors need to be considered in a setting of large natural biological variation. Moreover, coastal managers rarely have access to temporal data sets with the history needed to evaluate community state in the context of natural community dynamics.

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Biotic indices that translate complex ecological data into simpler metrics are sometimes used as communication tools for representing community states. Such indices are widely used for benthic macroinfaunal communities (Borja et al., 2000, 2014; Dauvin et al., 2012) where they have gained acceptance from coastal managers for characterizing the degree of anthropogenic perturbation (Borja et al., 2009; Díaz et al., 2004; Weisberg et al., 1997). In response to a call from the European Water Framework Directive (EC, 2000), efforts have been made to develop indices for phytoplankton (Revilla et al., 2009) and macroalgae (Orfanidis et al., 2001, 2003; Scanlon et al., 2007; Selig et al., 2007; Sfriso et al., 2009; Wilkinson et al., 2007), including attempts to develop indices for rocky intertidal and shallow, subtidal habitats (Ballesteros et al., 2007; Bermejo et al., 2012; Díez et al., 2012; Juanes et al., 2008; Panayotidis et al., 2004; Pinedo et al., 2007; Wells et al., 2007). However, for rocky coastal environments, these efforts remain on-going and a consensus has yet to be achieved on which rocky intertidal population and community responses serve to consistently differentiate natural from anthropogenic stress across different types of shores and geographic regions, an important property of a widely useful index (see Murray et al., 2006).

By their nature, rocky intertidal communities offer several challenges to evaluators of community state and to index development. First, these communities occupy heterogeneous habitats with considerable spatial and temporal variation in key abiotic environmental drivers. This can lead to multiple possible community structures that change over time, even for habitat patches within the same physical site, complicating efforts to evaluate ecological state. Second, rocky shore communities are simultaneously subjected to significant physical (e.g., wave action, sand scour, substratum instability, aerial emersion) and biological (e.g., predation) natural processes, whose effects are often difficult to differentiate from all but the most severe anthropogenic (e.g., poor water quality, trampling, harvesting) impacts. Third, the rocky intertidal zone is strongly influenced by tides, where submersion and emersion regimes limit the shore positions that can be occupied by most species (Knox, 2001; Raffaelli and Hawkins, 1999). This produces well known, vertical patterns of species abundances on the shore and makes it essential that community data used to determine and compare the ecological states of sites are obtained from samples taken over equivalent intertidal positions. Fourth, the composition, orientation (slope, aspect) and relief (rugosity) of the rocky substratum itself has a strong influence on species distributions and abundances, within and among sites (Schoch and Dethier, 1996; Wells et al., 2007).

A step toward advancing our understanding of anthropogenically impacted communities is to determine the level of consensus achieved by experts when asked to identify a community's ecological state based upon the response signatures captured by biological data. Best Professional Judgment (BPJ) exercises have been used successfully to make state judgments in many fields (Meyer and Booker, 2001). For example, in aquatic environments, BPJ has been used to evaluate and compare benthic indices (Borja et al., 2014; Dauvin et al., 2012; Ranasinghe et al., 2008; Teixeira et al., 2012), to determine consistency in judging sediment quality (Bay et al., 2007), and to ascertain the level of agreement in identifying the degree of disturbance in benthic macroinfaunal communities (Borja et al., 2014; Dauvin et al., 2012; Teixeira et al., 2010; Thompson et al., 2012; Weisberg et al., 2008). To our knowledge BPJ has yet to be used to evaluate the ecological states of rocky intertidal communities.

Here, we convened a team of rocky intertidal experts to conduct a BPJ exercise to determine: (1) the level of agreement in identifying the states of rocky intertidal communities and (2) which attributes of the biological data were found most useful in making state evaluations. We also assess how well the level of expert agreement attained for rocky intertidal communities compares with similar BPJ exercises performed to evaluate the ecological states of benthic macroinfaunal samples from soft bottom habitats where knowledge of biological indicators of anthropogenic stress is much more fully developed.

Table 1
Names and locations of western North American rocky intertidal sites containing macroorganism communities evaluated by experts.

Site name	Latitude (°N) (DD.DD)	Longitude (°W) (DD.DD)
Central California sites		
Pigeon Point	37.19	122.40
Año Nuevo	37.11	122.33
Hopkins Marine Station	36.62	121.91
Point Lobos	36.51	121.94
Hazard Canyon	35.29	120.88
Shell Beach	35.17	120.70
Stairs	34.73	120.62
Partington Cove	36.17	121.70
Lucia	36.01	121.54
Duck Pond	35.86	121.42
Terrace Point	36.95	122.06
Point Sierra Nevada	35.73	121.33
Southern California sites		
Buck Gully	33.59	117.87
Cabrillo: Zone 1	32.67	117.25
Crystal Cove	33.57	117.84
Dana Point	33.46	117.71
Heisler Park	33.54	117.79
La Jolla Caves	32.85	117.27
Lechuza Point	34.03	118.86
Old Stairs	34.07	119.00
Paradise Cove	34.01	118.79
Scripps	32.87	117.25
Sequit Point	34.03	118.86

2. Methods

Experts evaluated the states of rocky intertidal communities using biological data commonly collected in rocky intertidal sampling programs: site-scale data representing the abundances of macrophyte (macroalgae and surfgrasses) and macroinvertebrate (invertebrates discernible in the field with the unaided eye) populations. Similar procedures to those employed in BPJ exercises for benthic macroinfaunal communities were used (see Thompson et al., 2012; Weisberg et al., 2008). Biological and physical environmental data sets for a range of sites were collected, standardized, and given to each expert, and instructions for ranking and scoring site communities were provided so experts could prepare their evaluations.

2.1. Sites

Our study focused on 23 sites from western North America: 12 from central California and 11 from southern California (Table 1); sites were chosen from a potential pool of 34 central California and 31 southern California mainland sites for which comparable data sets were available. Selected sites had a geomorphology consisting primarily of rock outcrops or benches; sites composed largely of cobble or other unstable substrata were not included. Selected sites were distributed over most of the two study regions. Central California sites ranged from Pigeon Point (37.19° N; 122.40° W) to Stairs (34.73° N; 120.62° W). Southern California sites were located south of Point Conception, a major biogeographic boundary, and were distributed along the coastline from Old Stairs (34.07° N; 119.00° W) to Cabrillo Zone 1 (32.67° W; 117.25° W). Sites directly exposed to high levels of contamination, such as sewage or papermill discharges, were not available for sampling because current